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MINOR STUDIES FROM THE PSYCHOLOGICAL LABORATORY OF CORNELL UNIVERSITY

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XLIII. A Preliminary Study of the Psychology of Heat

By F. CUTOLO, JR.

The current view that heat is conditioned upon the simultaneous stimulation of warm and cold spots derives in the main from the work of Alrutz. He employed an areal stimulus which was adequate both to warmth and to paradoxical cold. When this stimulus was applied in a region where there were only cold spots, he found only cold; where there were only warm spots, only warmth; but where there were both cold and warm spots, he found a resulting experience which he calls a *Hitzempfindung* and which he regards as unique and not further analysable. "Pure introspection," he says, "tells me not only that 'hot' is something different in regard to quality from warm, and that hot can very well be experienced without pain (although pain often *does* accompany it), but also that hot is a simple sensation which *generally* cannot be cut up or analysed into component parts."¹

Alrutz also refers to certain experiments of Thunberg which he accepts as supplementing his own. Thunberg had simultaneously stimulated warm and cold spots by means of a flat coil of two small metal tubes. Through the one of these he ran warm, and through the other cold water, the temperatures being 44° and 24°C., respectively. Upon stimulation with this apparatus he got an experience which was "as if the temperature was suddenly raised and a feeling of 'hot' ensued." Coupled with this was "the sensation of a burning sensation about to arise." Thunberg, however, has never accepted Alrutz' notion of the *Hitzempfindung*; on the contrary, he regards the experience as a *Mischempfindung* which has the coloring of the stronger component, and which with sufficient practice may be analysed.² In this opinion he is supported by Kiesow, who explains the rise in intensity of the warmth in Thunberg's experiment as a contrast phenomenon, and the anticipatory "burning" as due to imagination. Kiesow thinks, moreover, that there may be all sorts and degrees of fusion among the various cutaneous qualities, and that cold and pain (whose limen varies at different parts of the body) are of especial significance for the qualitative coloring of these fusions. In illustration of the variation in the limen of pain, he gives the following instance, which, as we shall later see, may be of considerable importance: "Tauche ich die Nagelphalange des linken Zeigefingers in Wasser, das constant auf 49°C. erhalten wird, so bemerke ich nach wenigen Secunden auf der

¹ S. Alrutz, *Upsala Läkareförs. Förhandlr.*, N. F., 2, 1897, 340—359; *Mind*, N. S., 7, 1898, 141—144; *Skand. Arch. f. Physiol.*, 10, 1900, 340.

² Thunberg, *Upsala Läkareförs. Förhandlr.*, N. F., 1, 1896, 489 ff; Nagel's *Handbuch der Physiol. des Menschen*, 3, 1905, 707.

Dorsalseite, an den Rändern, vorn unter dem Nagel ausgesprochenen Schmerz, während dieser auf der Volarseite des Fingergliedes nicht auftritt. Lege ich die Volarseite der Phalange auf die Oberfläche des Wasser, so muss ich dasselbe bis auf 51°—52° erwärmen, um hier Schmerz zu empfinden. Zuweilen kündigt sich dabei die Schmerzempfindung an, *ohne deutlich ausgesprochen zu sein*. Diesen Zustand habe ich als *schmerzbetont* bezeichnet.”³

Heat, for Kiesow (who has repeated Alrutz' experiment), is always obtained from temperatures near, at, or above the pain limen, and is therefore either *schmerzbetont* or painful; it is different from the characteristic “vollwarme Empfindung;” and at 45° occurs a complex which sometimes breaks up under analysis into warmth and cold, sometimes shows only a fluctuation of these two qualities.⁴

The issue is plain enough. All three observers agree that with areal stimulation there may be a mixture or fusion of cold and warmth, but they disagree as regards both the simplicity or complexity of the experience and the qualitative nature of heat.

In our own attack upon the problem we have employed two methods of stimulation: (1) a punctiform simultaneous stimulation of warm and cold spots, a method which has not heretofore been used and which would seem to simplify the issue; and (2) a repetition of Thunberg's experiment, substituting for the coil a grill of warm and cold stimuli. The observers were E. G. Boring (B), instructor in psychology, who has had long experience in qualitative descriptions of cutaneous and organic sensation, and J. M. Gleason (G) and M. Kincaid (K), graduate students in psychology. B and K had had previous experience in the analysis of heat, and worked in these experiments with knowledge: G, on the other hand, although an observer of experience, had only a short preliminary practice in the analysis of heat, and worked without knowledge. We shall discuss the two experiments separately.

Series 1. Punctiform Stimulation. We employed, in this series, the Zimmermann thermaesthesiometer, with cold water running through the one point, and warm through the other. The temperature of the warm water was always 44° or 45°C;⁵ that of the cold, while constant for a single period, ranged from 8.25° to 13.5°. The flow of water (from large pails) was rapid, and the fall in temperature was never as much as one degree. The temperature of the room during the periods of experimentation ranged between 16° and 21°C. We worked on the forearm. The absolute position of the cold and warm spots was noted in mm. from the carpal folds, and their relative position in terms of the angle of the line which connected them. Directions were indicated as peripheral (P) or towards the wrist, central (C), right (R), left (L). The area of the cutaneous surface was included between cross-lines 2 and 40 mm. from the carpal folds, and the distance between the spots varied from 2 to 9.3 mm. The period of stimulation (measured by a soundless metronome) was for the most part five sec-

³ F. Kiesow, *Zeit. f. Psychol. u. Physiol. d. Sinnesorg.*, 26, 1901, 237 (italics ours).

⁴ *Op. cit.*, 237 f.

⁵ We found it necessary to employ these high temperatures in order to secure a definite warmth-response from the warm spots. Our check against both pain and paradoxical cold was introspective and positive. In the preliminaries no observer ever reported either pain or cold when a warm spot alone was stimulated with a temperature of 45°. With dual stimulation of both warm and cold spots, neither pain nor cold was reported at the place where the warmth was localized.

onds. The instruction for B and (in the earlier series) for K read as follows: "After the signals 'ready,' 'now,' a stimulus will be placed on your skin for a short interval. When it has been removed, give as complete an introspective description of the sensory experience as you can. In the description you should enumerate as many sensory components as you can find, and characterise every component as fully as possible." For G and (in the later series) for K, the last phrase of the instruction read "*Describe or characterize every sensory component as fully as possible.*"

Results of Punctiform Stimulation. The experience resulting from this method of stimulation is extraordinarily complex. Warmth, cold, pressure and heat may appear in succession, or two (sometimes three) of them may exist side by side. One component may change in intensity and fade out, and another familiar quality may take its place; a component may suddenly disappear, giving way to a new complex which all but baffles description. No two patterns are ever exactly alike, and the same two spots rarely give the same spatial and temporal patterns at different times even when stimulated with the same intensities. The task set our observers was therefore difficult, and it was made no easier by the general nature of the instruction. For the term "heat" could not be employed without prejudice, and the analysability of every complex was of course assumed. Despite these difficulties, however, all three observers reported the presence of heat or its equivalent. They have furnished us with a provisional description of its nature, and with a general picture of the spatial and temporal patterns for the total period of stimulation. We shall reverse this order in our discussion, and we begin with a few typical introspections:

B. "The heat was set in a fringe of warmth." "First cold, then a flash of warmth, then heat for a long long time; . . . most of the time no warmth or cold with it, but often a faint tinge of warmth, a sort of a halo very weak and thin that came and went. Two or three times . . . a tinge of cool, not a fringe but a little vague blotch, very faint, at one side." "A moderate cold, then strong heat, with a little warmth on one side of the heat and a little cold on the other."

G. "First a stinging heat, a small line of it. Almost immediately a sticky cold came around it, then the entire area got cold. Following this, a flash of heat came back in one spot of the cold area; this then disappeared and a diffuse warmth came round the cold patch." "First a line of intense warmth running on the PC direction; almost immediately, at the end of the line, a little area of cold. Very light contact along the warmth line, and heavier contact at the cold; the former was quite diffuse and irregular, a feathery thing, whereas the latter was compact, round and even. The warmth then spread out over the cold."

K. "Immediately following the initial pressure, quite an intense warmth with a slight pain element, a sharply localised, bright, penetrating, denting sting. This faded out rather abruptly, becoming a more diffused localized warmth, with an adjacent spot of cold." "First pressure at a single point, then warmth at the same point. The latter was very thickly concentrated; it seemed heavy and blunt, not spreading out with faint boundaries as usual. There was perhaps also a tiny pin-point of sting; of this I am not sure. At quite a distance there seemed to be hovering a faint cold; this did not seem to be on the skin but above it."

B reported the temporal order of the components in 24 of the 25 experiments in which he observed. Cold was reported first 21 times, heat twice, and pressure once. The second experience reported was heat 16 times, warmth 7, and cold 2. The third was cold 9 times, heat 4, pressure 2, and warmth once. Cold was at once followed by heat in 65%, by warmth and then heat in 17% of the cases. In two cases cold was followed by warmth and no heat appeared. Heat was most frequently followed by cold (11 times); in 7 cases, however, heat was present when the stimulus was removed.

G observed in 16 experiments, and heat was reported in 9. She was not so certain of the temporal order as was B; frequently two qualities were reported as appearing simultaneously. But, without doubt, the first experience was cold 11 times, heat 3, and warmth 2; the second was warmth 7, heat 4, and cold 2; the third was warmth 4, heat 3 and cold 1. Cold was followed at once by heat in 3 and by warmth and then heat in 3 of the 9 cases. Six times heat was followed by cold; twice by warmth.

K took part in 29 experiments. She was disposed to report the spatial rather than the temporal pattern. It is clear, however, from her introspections that in about half the cases the first impression was a cold pressure, and in the other half warmth either alone or accompanied by "sting." The second experience was most frequently sting either alone or accompanied by warmth; the third was usually cold, although warmth-plus-sting was often present without cold at the close of the experiment.

It will be seen that for all observers cold (aside from pressure) is generally the first quality to appear. This has also been observed by Alrutz, and accords with the fact that the reaction time of cold is shorter than that of warmth.⁶ Another tendency too general to be meaningless is the continuation of cold after heat has disappeared. This was also found with areal stimulation by Alrutz, who supposes that the warmth adapts more quickly than the cold.⁷

The Nature of Heat. B reported heat in 23 of 25 observations, G in 9 of 16, and K reported what we believe to be its equivalent in 18 (possibly 19) of 29. Since we shall have more to say about heat after we have considered the second series of experiments, we shall here merely indicate the nature of the experience as thus far reported.

B began the series by referring to heat as an unique but not necessarily simple experience, the main characteristic of which was a quality something like pressure and something like pain. In the 5th experiment he calls this quality "sting," and describes it further as flat like pressure, bright like pain, and as having the promise but lacking the thrust of pain. Later he employs the term "smack" instead of sting, and describes this as smoother, and thus more like pressure, than pain. These two terms serve for the description of heat throughout the remainder of the series. Some heats are like smack, others like strong sting, some lie between pressure and smack, still others between smack and sting. B came to think of heat, therefore, as a simple quality lying in a series consisting of pressure, smack, sting, and pain; and this is analogous to a color-series like green, greenblue, bluegreen, and blue. In true heat no warmth or cold is discoverable; "psychologi-

⁶ *Mind, loc. cit.*, 142; A. Goldscheider, *Ges Abhandl.*, 1, 1898, 299; Thunberg, *Skand. Arch. f. Physiol.*, 11, 1901, 414 f.

⁷ *Mind, loc. cit.*, 143.

cally," he says, "it is laughable to think of heat as conditioned upon warm and cold." There are, however, some warm-heats, and he found at least one cold-heat; in these instances heat could be separated by analysis from the warmth or cold and examined alone.

Neither of the other two observers came to the experiment with more than a casual experience with other cutaneous qualities; and although both hit upon the term "sting" for the characterization of heat, and although both reported stings without warmth or cold, neither was able to distinguish clearly between sting and pain. K, indeed, seems at times to have made no distinction between the two experiences, "Cold," she reports, "was followed by pain (*i. e.*, sting; penetrating, concentrated but not very intense)." On other occasions she characterised the experience as "a sharply localised, bright, denting sting;" "a sting, very penetrating, sharp, conical;" "a large, heavy, diffuse pain (sting);" "a sting faint, delicate, slightly denting." G, on the other hand, was content with the description of heat as sting, and did not attempt to relate it to pain. On one occasion, however, she speaks of a "stingy pain," on another of "burning heat," and on two others of "burning pain."

Series 2. Grill Experiments. In this series we employed an areal stimulus, which consisted of a surface made of 8 glass capillary tubes, with warm water running through the even and cold through the odd numbered tubes. These tubes had an outside diameter of 6.5 or 7 mm., and a length of 18 cm. They were laid parallel, and as nearly apposed as the slight imperfections in the surface of the glass would allow, and in this position were fastened by wooden cleats to the board which served as arm-rest. The area between the cleats, 9.5 x 5.6 cm., was the surface employed as stimulus. The ends of the glass tubes were connected by rubber tubing, in the one case with the waste-pipe, in the other with T gas-pipes which in turn were connected with stop-cocks controlling the two streams of water. The warm water was furnished from a galvanized-iron tub holding about 15 gals.; the temperature, constant for an experiment, varied throughout the series from 43° to 45°C. The cold water came directly from the tap of the water supply, and ranged in temperature from 5° to 9°C. The procedure was as follows: O laid his forearm (occasionally his hand) on the grill, and the warm water was turned on and allowed to run until warmth was reported. Then the signal "now" was given, and the cold water was also turned on. The instructions were: "The experimenter will adjust the apparatus until you feel only warmth (and pressure) from the grill. At the signal "now" close your eyes and note the course of the sensation that ensues upon the warmth. If it is of any assistance to you, keep up a running verbal account aloud while the changes are in progress. After the trial you will be asked to describe the complete experience. Enumerate the sensory components and characterise them whenever possible, especially with regard to quality." All observers accepted the suggestion of the instruction, and gave running verbal accounts of the experience during its course. For this reason the time of application of the stimulus was indefinite, depending upon the nature of the report.

We had no intention of carrying out a carefully controlled series of experiments with this method. We hoped (1) to find an easy means of demonstrating the fact that heat may be derived from a simultaneous stimulation by warm and cold. We desired (2) to control for purposes of observation the course of the psychological experience (we could begin or end the period of stimulation with either warm or

cold, or both, or neither). And we were interested (3) in comparing the qualitative results thus obtained with those found by punctiform stimulation.

Results of the Grill Experiments. We found that this method is excellent for demonstration. The apparatus is simple in construction, and even the untrained observer can easily convince himself that heat derives from warm and cold stimulation. Moreover, the temporal course of the experience was under control; it could be made to begin with warmth, instead of with cold as in the punctiform series; and when cold ensued after heat, it is possible to reverse the order of change by turning off the cold and allowing the warm water to continue running. B did not generally report the temporal patterns; but G found that heat without cold always followed the initial warmth, except when the temperature of the cold water was as low as 5°, in which case heat came with cold. In 6 of 11 cases the initial warmth was reported to increase in intensity before heat came in, and in one instance "pain" appeared before the signal "now," i. e., before the cold stimulus was applied. K also reported "sting" as the second experience in the majority of cases, and cold-plus-sting twice. She also found warmth present with sting twice before the signal "now." This latter experience is to be expected, since the temperature of the warm water was adequate to paradoxical cold.

All observers report heat (sting, stingy-pain) without temperature; heat with cold or warmth present but spatially different; warm-heats, and cold-heats. B substantiates his results obtained by punctiform stimulation, and concludes that "true heat" is a simple pressure-pain quality, with no trace of warmth or cold in it, and that warm-heat and cold-heat are fusions. He thinks that normal heat, the typical heat of every-day life, is a warm-heat or heat with warmth fringes or halos; and that cold-heat definitely carries the meaning of heat, and yet has cold in it instead of the typical component of warmth. Finally, he is less sure of the applicability of the terms "smack" and "sting" to the description of heat. He says: "they seem a little more complex than when I first used them;" and again, "I tried hard to get a better description of heat but without success. "Smack" is good, but it doesn't seem persistent enough; 'tear' is all right, but it doesn't seem penetrating enough; 'drawing' is all right, but it sounds as if it might be just pressure." "It's a true pressure-pain, I am sure, and it is not at all a true pressure or a true pain. It is between pressure and the painful part of ache. A drawing, tearing quality is the best I can do for heat verbally." K continues to employ the term "sting," apparently with the meaning of pain; and G, in this series, always uses the terms "stingy pain" or "burning pain," and characterises the latter as a stingy pain with warmth in it.

Conclusion. We agree with Alrutz that heat, a cutaneous quality that is neither warmth nor cold, may result from the simultaneous stimulation of warm and cold spots. We do not agree with Thunberg that heat is a *Mischempfindung*; we find, rather that heat itself mixes and fuses with warmth or cold; that there may be spatial mixtures, and probably fusions of warm and heat or of cold and heat at the same place. But our observers are not agreed as regards the presence of the quality of pain in the experience of heat: our most experienced observer, B, believes with Alrutz that heat may occur without pain; whereas our other observers employ the terms sting and stingy pain

to characterise the experience.⁸ These two observers, therefore, would support the contention of Kiesow. We are inclined, however, to accept the view that true heat is not true pain. For (1) neither of our two observers who report the experience as "sting," meaning thereby pain, has had more than a casual acquaintance with the qualities of pain. These observers were not, therefore, adequately prepared to distinguish between true pain and heat. (2) The meaning of heat in everyday life is undoubtedly associated with pain; so that even if heat may exist without pain, it nevertheless points towards pain. (3) This fact, taken together with B's characterization of psychological heat as a quality lying between pressure and pain, makes intelligible Thunberg's "sensation of a burning sensation about to arise," B's expression "heat with a promise of pain," and Kiesow's *schmerzbetonte Empfindung*. We do not, however, regard the matter as settled. Kiesow's contention that heat can be obtained only with stimuli near, at, or above the pain limen, can be fully met only by reproducing the experiences reported in this paper with stimuli that are beyond the shadow of a doubt inadequate to pain; *i. e.*, with a warm stimulus that is inadequate to paradoxical cold, and with a cold stimulus that proves experimentally to be inadequate to ache in the region of the cutaneous surface chosen for experimentation. The next logical step along the lines of this investigation is accordingly the correlation of heat and its fusions with various combinations of temperatures of warm and cold stimuli.

⁸ It may be said that B was disposed *a priori* to find heat "a pain" or "pain." His descriptive report was, therefore, contrary to the lines of autosuggestion.